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Spectroscopic changes in conventional magnetorheological fluid and graphene oxide based magnetorheological fluid with combustion method

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Abstract: A comparative spectroscopic analysis of conventional Magnetorheological fluid and Graphene Oxide based Magnetorheological fluid. Raman spectra have been recorded using 532 nm laser excitation. The down shifted G-band of Graphene Oxide observed at 1576.42 cm^{-1} due to the doubly degenerate zone center E2g mode and 2D band at 2702.58 cm^{-1} confirms the presence of Graphene Oxide. UV - VIS Absorption spectrum of GO based MR fluid has been recorded of π-π plasmon peak at 233.82 cm^{-1} while a broad band is displayed in conventional Magnetorheological fluid. Here, Graphene Oxide used in Magnetorheological fluid is prepared by combustion method of separating Graphene layers by controlled oxidation. This analysis shows highly efficient, unequivocal, non-destructive identification of Graphene Oxide in Magnetorheological fluid.

INTRODUCTION

Graphene Oxide based Magnetorheological fluid is a controllable active smart material which can respond precisely to external magnetic field by aligning along the lines of magnetic flux, forming a chain like microstructure which opposes the flow. It consists of polarizable particles suspended in a nonmagnetic carrier medium. In the absence of magnetic field, Graphene oxide occupies the interspaces between the magnetic particles to restrain the direct contact of these particles, consequently sustaining the stability of MR fluid, due to its structurally supportive amphiphilic nature. Furthermore, stabilizing polarizable particles in the base fluid. In the presence of magnetic field, these dispersed particles polarizes, forming assembled chain-like micro-structure along with Graphene oxide filled in the space of body-centered pentagonal structure of iron particles under van der Waals interparticle interactions.

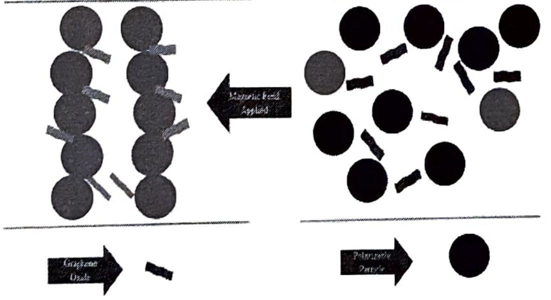

Fig.1. Schematic diagram of GO based MR fluid

EXPERIMENTAL PROCEDURE

Raman spectroscopy

Raman spectra were recorded using RIRM Direct Coupled Raman Spectrometer, an excitation laser source at 532 nm, dual sample holder (Vertical and Horizontal), and a charge-coupled device (CCD) detector. Analysis of samples with a microscopic laser spot using high quality lens and filters with 10x long working distance, a 200mW tunable laser power, a spectral range from 120 to 4500 cm^{-1} with an optical resolution of 1 to 3 cm^{-1}, a precise stage height movement, a direct coupled air free optics. The acquisition time was of 2 scans with 4500ms exposure time.

UV-Visible spectroscopy

UV-Visible absorption spectra was recorded using RI2AS spectrometer, a balanced deuterium halogen composite light source (deuterium lamp emitting a continuous spectrum of light ranging from 190-400 nm in the UV range to 400-800 nm in visible light, tungsten halogen lamp emitting light ranging from 360-2000 nm), a spectral range from 190-2500 nm, an optical resolution of 0.03-8.4 nm, sensitivity of 161000 counts/μW per millisecond integration time, focal length of 110 mm, 6:1 round to linear fiber, detector collecting lens and order sorting filter. The acquisition time was 51 scans with 2ms exposure time.

RI software features

Instrument control and data collection parameters are user definable, such as exposure time, dark correction, signal averaging, spectral smoothing, and automatic saved spectra. Graphics saved in .txt format and can be opened in any third-party software e.g. Origin, Excel and other data processing software.

Comparative analysis

Graphene oxide based Magnetorheological fluid fingerprint is quite different from conventional Magnetorheological fluid and it can be easily identified by the Raman spectra.

Through Raman spectroscopy it is possible to monitor the changes in the morphology of different Magnetorheological fluids since C-C and C=C symmetric vibrations of the aromatic rings have a strong change of polarizability of their electronic cloud inducing a strong Raman Effect. Absence of less intense D peak indicates absence of significant number of defects. It was only observed in the sample of Graphene Oxide.

Magnetorheological fluid has several characteristic sharp bands at about 488.50 cm^{-1} representing Fe-CO stretching [2], 1069.88 cm^{-1} corresponding to Si–O–C stretching, asymmetric deformation vibration of the CH_3 group at 1413.94 cm^{-1}, characteristic sharp band at 1260 cm^{-1} due to the symmetric deformation of methyl groups, asymmetric and symmetric stretching vibration of C-H at 2800-3000 cm^{-1} [1]. Graphene oxide based Magnetorheological fluid has same characteristic bands including two more bands at 1576.42 cm^{-1} representing in plane vibration of c-c bond corresponding to the E2g symmetry and an evolved broad band at 2702.58 cm^{-1} [3].

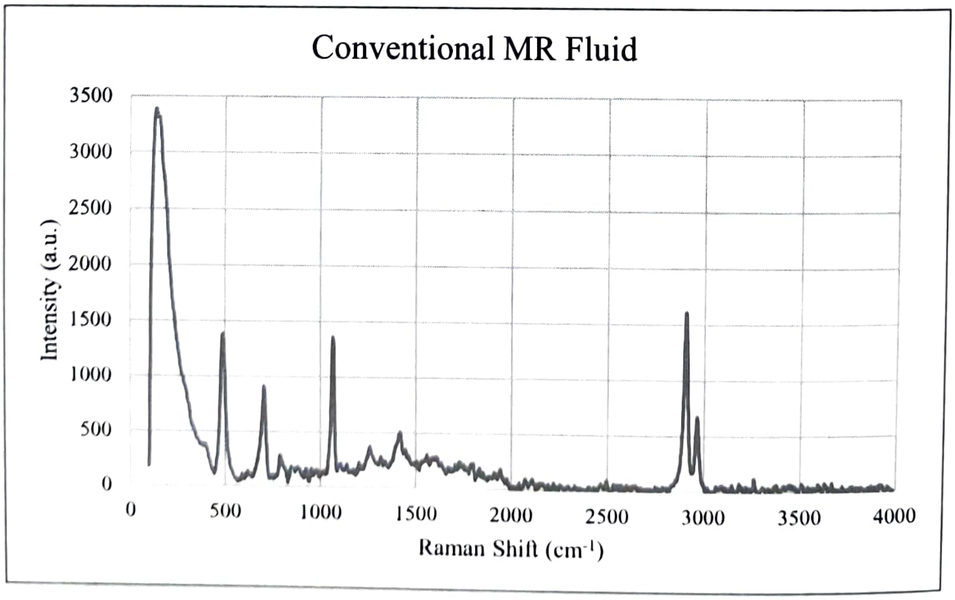

Fig.2. Raman spectrum of Conventional MR fluid

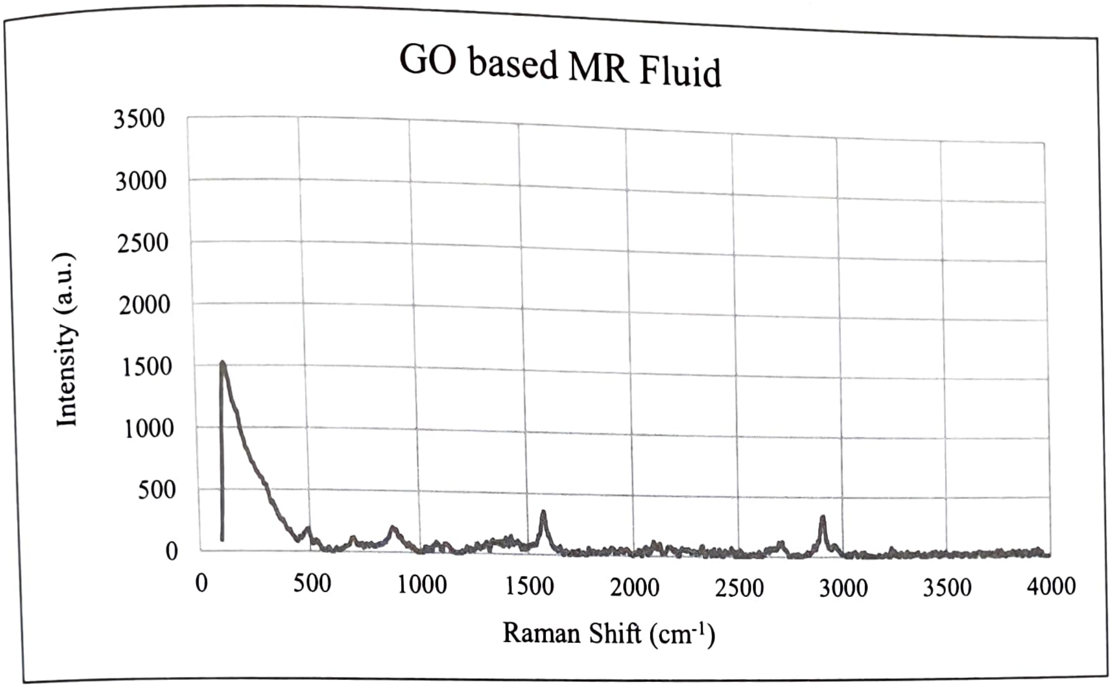

Fig.3. Raman spectrum of GO based MR fluid

In UV-VIS Absorption spectra, it can be inferred that optical absorption of Graphene Oxide in Magnetorheological fluid is dominated by the π-π plasmon peak near 233.82 nm depending on nanometer-scale sp2 clusters and linking of chromophore units like C=C, C-C, C=O bonds while in absorption spectrum of Conventional Magnetorheological fluid, this peak is absent [4].

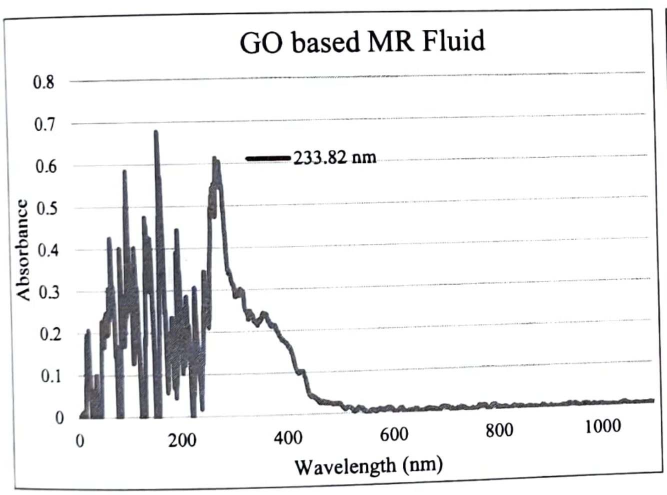

Fig.4. Absorption spectrum of GO based MR fluid

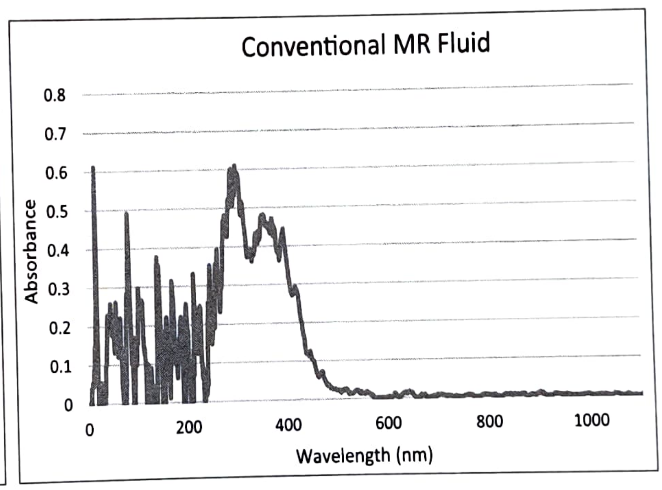

Fig.5. Absorption spectrum of Conventional MR fluid

Stability of Graphene Oxide based Magnetorheological Fluid as compared to Conventional Magnetorheological fluid

Because of the large density mismatch between dispersing (0.967 gm/ml) and dispersed phase (7.8 gm/ml), magnetic particles tends to settle down at the bottom. For the quantitative analysis of sedimentation rate, a simple experiment was performed [5]. Two falcon tubes of 50 ml were taken and filled with conventional and GO based Magnetorheological fluid. The phase boundary separating Magnetorheological fluid from the supernatant was observed over a period of time.

Following equation was used for sedimentation rate calculation:

Sedimentation Ratio = Volume of supernatant fluid / Total volume of Magneto rheological fluid × 100

Fig.6. represents the sedimentation ratios of the two Magnetorheological fluids. Conventional Magnetorheological fluid has the sedimentation ratio of 34.61% and Graphene Oxide based Magnetorheological fluid has sedimentation ratio of 0.02%.

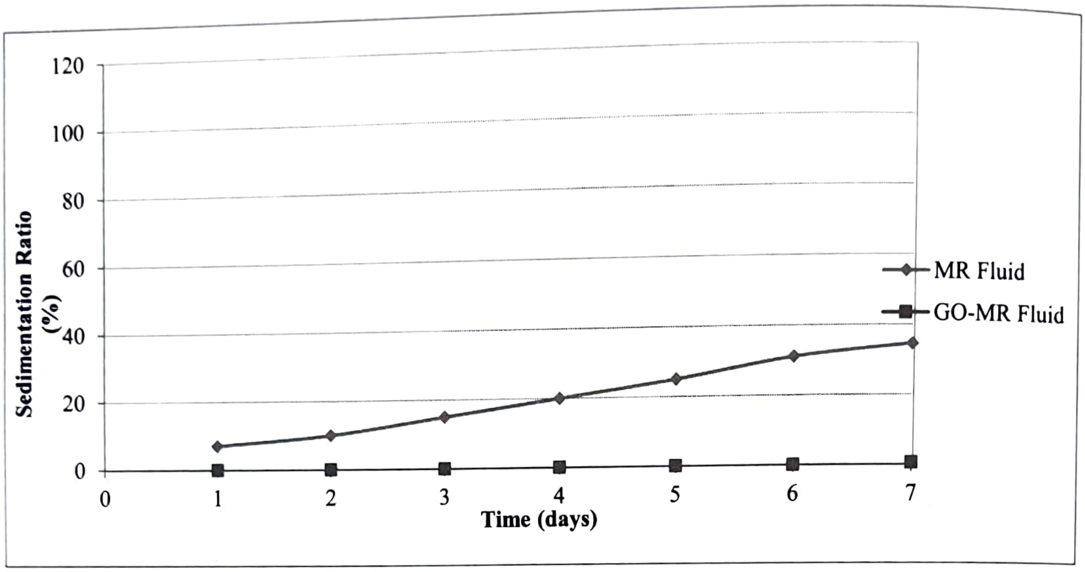

Fig.6. Sedimentation rate of MR fluids

It was observed that GO based Magnetorheological fluid was well dispersed and stable for a period of 7 days. Thus, in terms of sedimentation ratio, Graphene Oxide based Magnetorheological fluid is more suitable for real-time torque transmission applications.

This test reveals that Graphene Oxide based Magnetorheological fluid is one the best candidate for overcoming the problem of high sedimentation rates.

Stability of the fluid is crucial in every torque transmission industrial application including shear, valve and squeeze mode operations. Thus, optimum concentration of Graphene Oxide is desirable for stability enhancement of Magnetorheological fluid. Graphene oxide based Magnetorheological fluid shows no sedimentation after qualitative observation of over two months. The samples were kept under observation and photographed before and after 7 days.

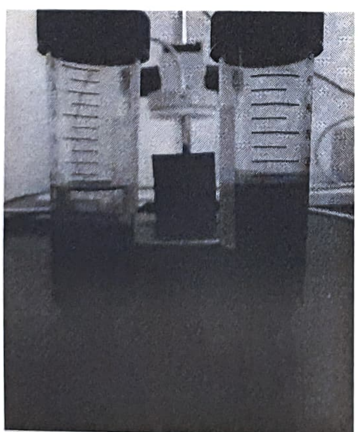

Fig.7. (a) MR fluid on the left hand side & GO Based MR Fluid on the right

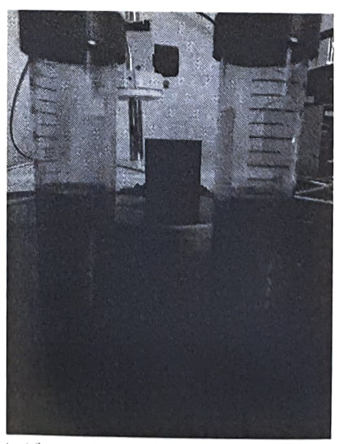

Fig.7. (b) After 7 days sedimentation of MR fluid on the left hand side & GO Based MR Fluid on the right hand side

CONCLUSION

A new approach to directly capture Graphene Oxide based Magnetorheological fluid in Raman Spectrum which is clearly different from the Spectrum of Conventional Magnetorheological fluid. Presence of Graphene Oxide in Magnetorheological fluid increased sedimentation stability, directly increasing the shelf life of Magnetorheological fluid. The Raman Spectra of both Magnetorheological fluids reflect changes in the electronic structure and electron-phonon interactions allowing unequivocal, highly efficient, non-destructive identification of Graphene Oxide in Magnetorheological fluid.

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